Rainfall Analysis and Discharge Estimation for the July 27, 2014 Flow Event on Sonoita Creek

Prepared For:

HUDBAY

Rosemont Copper Project

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Water & Earth TECHNOLOGIES

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1.0 Introduction

Water & Earth Technologies, Inc. (WET) is providing engineering analysis and design services to Hudbay in developing a project intended as mitigation for ephemeral stream channels impacted by the Rosemont Copper Project (Project). The Sonoita Creek mitigation project involves retiring agricultural land adjacent to Sonoita Creek from cultivation and implementing a variety of stream restoration measures to reduce or reverse the adverse impacts of historic straightening and entrenchment of the ephemeral stream channel. Conceptual design for the project has been completed using design discharges developed theoretically, since no stream gages exist on the reach of Sonoita Creek considered for restoration. A relatively large storm event which occurred on July 27, 2014 provides an opportunity to "reality check" the watershed response predicted by the project's hydrologic and hydraulic modeling results, using rainfall data recorded during the storm by a precipitation gage in the project area and using high water marks left by the resulting flow event in Sonoita Creek.

2.0 Rainfall Analysis for the July 27, 2014 Flow Event

On July 27, 2014 a significant monsoon storm occurred in the vicinity of the proposed mitigation and stream restoration project on Sonoita Creek. ALERT data from the Santa Cruz County Flood Control District were obtained to determine the magnitude of the storm. The ALERT network for the county is shown in Figure 1, with the project area circled in red.

The ALERT precipitation gage closest to the project site is gage #2520, located at Casa Blanca Canyon and Hwy 82. This gage recorded a 24-hour total of 2.76 inches on July 27, 2014. Based on this amount of measured rainfall, the NOAA Atlas 14 table relevant to the project site (for the Patagonia, Arizona area) (Figure 2) indicates that this storm was between a 2-year (2.3 inches) and 5-year (2.86 inches), 24-hour event.

3.0 Peak Discharge Reconstruction

The peak discharge occurring at the project site during the 2014 monsoon season (most likely as a result of the July 27, 2014 storm) was estimated based upon a forensic hydraulic analysis of high water marks observed in the Sonoita Creek channel. Data for a hydraulic model were collected during a site visit that was conducted in January 2015 to assess field conditions and identify effects of the 2014 monsoon season. During this visit, a concrete road crossing and structural control on the south (downstream) side of the project location was identified as a favorable location for estimating peak discharge based upon post-event hydraulic evidence.

Figure 3 and Figure 4 are photos from the site visit that show the road crossing. The width of the concrete crossing estimated from the photos is approximately 15 feet. On the downstream side of the crossing there is an immediate drop off of approximately 1 foot to the earthen channel. High water marks were identified in the field and can be clearly seen in the photo (Figure 4). Maximum water depth was approximately 2 feet on the left side (looking downstream) of the cross section, where the concrete road crossing is lowest. The right side of the stream cross section at the concrete crossing is slightly higher and high water marks there were shallower at just over 1 foot.

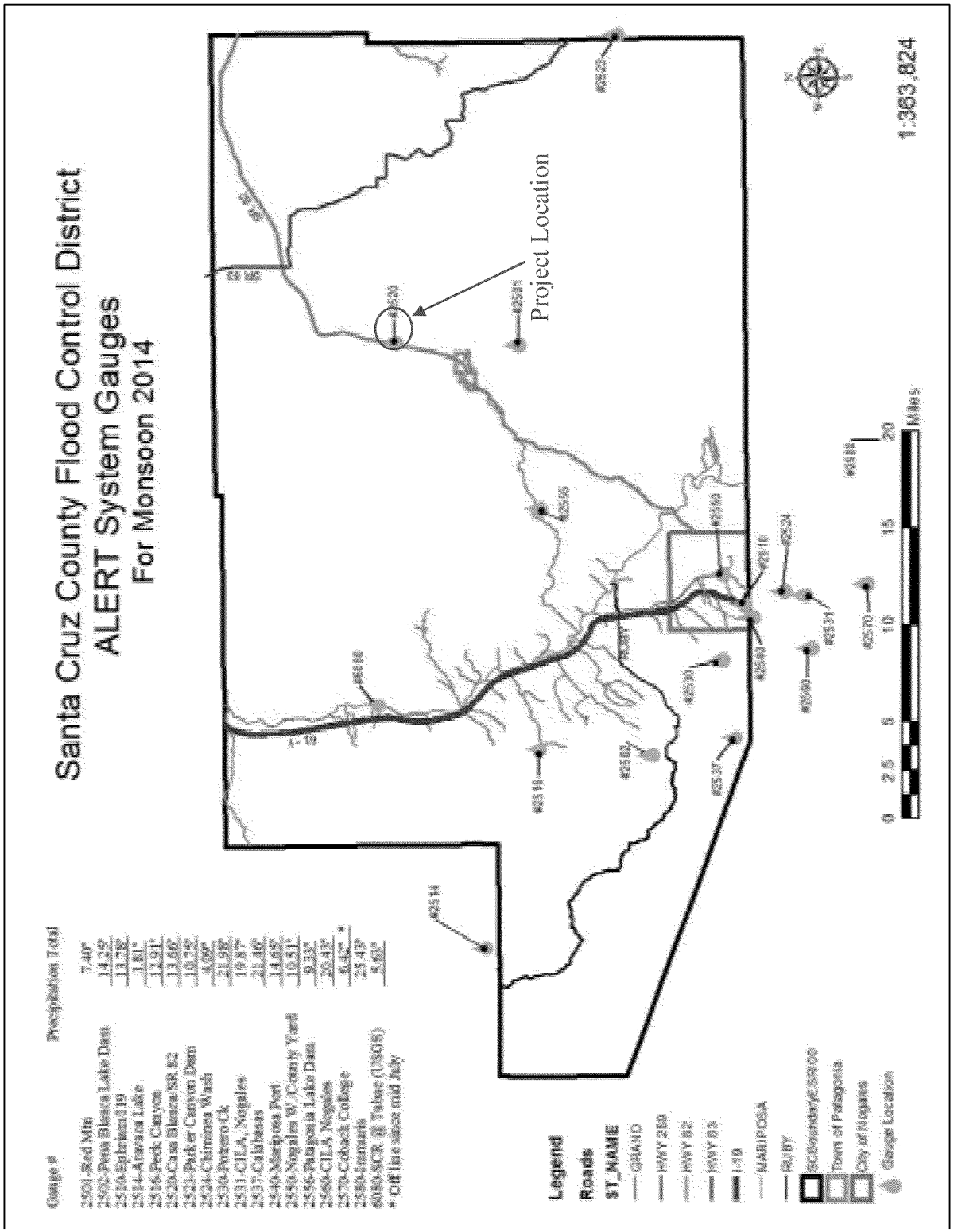

Figure 1. ALERT Network for Santa Cruz County

NOAA Atlas 14, Volume 1, Version 5
Location name: Patagonia, Arizona, US*
Coordinates: 31.6541, -110.7323
Elevation: 4594 ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

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NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.339 (0.303-0.382)	0.435 (0.388-0.490)	0.565 (0.502-0.634)	0.660 (0.585-0.740)	0.786 (0.690-0.880)	0.878 (0.765-0.988)	0.972 (0.837-1.10)	1.06 (0.907-1.21)	1.18 (0.988-1.35)	1.27 (1.05-1.48)
10-min	0.516 (0.461-0.582)	0.663 (0.591-0.746)	0.860 (0.764-0.965)	1.00 (0.890-1.13)	1.20 (1.05-1.34)	1.34 (1.16-1.50)	1.48 (1.27-1.67)	1.62 (1.38-1.84)	1.80 (1.50-2.06)	1.94 (1.60-2.25)
15-min	0.640 (0.572-0.721)	0.821 (0.732-0.925)	1.07 (0.947-1.20)	1.25 (1.10-1.40)	1.48 (1.30-1.66)	1.66 (1.44-1.86)	1.83 (1.58-2.07)	2.01 (1.71-2.27)	2.23 (1.86-2.56)	2.40 (1.98-2.79)
30-min	0.861 (0.770-0.972)	1.11 (0.986-1.25)	1.44 (1.27-1.61)	1.68 (1.49-1.88)	2.00 (1.75-2.24)	2.23 (1.94-2.51)	2.47 (2.13-2.79)	2.70 (2.30-3.06)	3.00 (2.51-3.44)	3.24 (2.66-3.75)
60-min	1.07 (0.953-1.20)	1.37 (1.22-1.54)	1.78 (1.58-1.99)	2.08 (1.84-2.33)	2.47 (2.17-2.77)	2.76 (2.41-3.11)	3.06 (2.63-3.45)	3.34 (2.85-3.79)	3.71 (3.11-4.26)	4.01 (3.30-4.65)
2-hr	1.18 (1.06-1.32)	1.50 (1.35-1.69)	1.93 (1.72-2.16)	2.26 (2.00-2.52)	2.71 (2.39-3.03)	3.06 (2.67-3.42)	3.42 (2.95-3.85)	3.78 (3.22-4.28)	4.27 (3.56-4.88)	4.66 (3.82-5.37)
3-hr	1.24 (1.11-1.38)	1.55 (1.40-1.74)	1.97 (1.77-2.20)	2.30 (2.06-2.57)	2.77 (2.46-3.09)	3.13 (2.75-3.50)	3.52 (3.04-3.96)	3.91 (3.33-4.42)	4.45 (3.70-5.09)	4.88 (3.97-5.65)
6-hr	1.42 (1.27-1.60)	1.77 (1.59-2.00)	2.23 (1.98-2.50)	2.60 (2.31-2.92)	3.13 (2.75-3.52)	3.56 (3.08-4.01)	4.01 (3.42-4.54)	4.47 (3.76-5.10)	5.11 (4.19-5.89)	5.63 (4.52-6.56)
12-hr	1.66 (1.50-1.85)	2.08 (1.87-2.32)	2.59 (2.31-2.89)	3.01 (2.68-3.35)	3.60 (3.17-4.00)	4.06 (3.55-4.54)	4.55 (3.92-5.12)	5.06 (4.29-5.73)	5.75 (4.77-6.59)	6.30 (5.12-7.29)
24-hr	1.85 (1.67-2.03)	2.30 (2.09-2.54)	2.86 (2.59-3.15)	3.30 (2.98-3.64)	3.91 (3.51-4.31)	4.37 (3.91-4.82)	4.85 (4.32-5.36)	5.33 (4.72-5.89)	5.98 (5.25-6.63)	6.48 (5.65-7.37)
2-day	2.04 (1.86-2.25)	2.54 (2.31-2.80)	3.14 (2.85-3.46)	3.64 (3.30-4.01)	4.34 (3.92-4.78)	4.89 (4.39-5.39)	5.47 (4.88-6.03)	6.07 (5.37-6.71)	6.89 (6.03-7.67)	7.55 (6.54-8.44)
3-day	2.22 (2.02-2.45)	2.77 (2.52-3.06)	3.43 (3.12-3.79)	3.98 (3.61-4.39)	4.76 (4.29-5.24)	5.37 (4.82-5.92)	6.02 (5.36-6.65)	6.70 (5.92-7.41)	7.63 (6.66-8.49)	8.38 (7.23-9.36)
4-day	2.41 (2.19-2.66)	3.00 (2.73-3.31)	3.72 (3.39-4.11)	4.33 (3.92-4.77)	5.18 (4.67-5.71)	5.86 (5.25-6.46)	6.58 (5.85-7.26)	7.33 (6.46-8.11)	8.37 (7.29-9.31)	9.20 (7.93-10.3)
7-day	2.90 (2.64-3.20)	3.62 (3.29-3.99)	4.51 (4.10-4.98)	5.23 (4.74-5.77)	6.22 (5.62-6.87)	7.00 (6.29-7.73)	7.81 (6.97-8.64)	8.63 (7.66-9.58)	9.77 (8.56-10.9)	10.7 (9.25-11.9)
10-day	3.37 (3.08-3.70)	4.21 (3.85-4.62)	5.21 (4.75-5.72)	6.00 (5.47-6.58)	7.06 (6.41-7.75)	7.87 (7.11-8.64)	8.70 (7.81-9.58)	9.53 (8.50-10.5)	10.6 (9.39-11.8)	11.5 (10.1-12.8)
20-day	4.66 (4.28-5.08)	5.82 (5.35-6.35)	7.14 (6.55-7.79)	8.14 (7.46-8.87)	9.43 (8.61-10.3)	10.4 (9.44-11.3)	11.3 (10.2-12.3)	12.2 (11.0-13.4)	13.4 (12.0-14.7)	14.2 (12.7-15.7)
30-day	5.88 (5.41-6.39)	7.33 (6.75-7.97)	8.93 (8.20-9.70)	10.1 (9.27-11.0)	11.6 (10.6-12.6)	12.6 (11.5-13.7)	13.6 (12.4-14.9)	14.6 (13.3-15.9)	15.8 (14.3-17.3)	16.7 (15.0-18.3)
45-day	7.27 (6.70-7.88)	9.05 (8.33-9.82)	10.9 (10.0-11.8)	12.2 (11.2-13.3)	13.9 (12.7-15.1)	15.0 (13.7-16.3)	16.1 (14.7-17.6)	17.1 (15.6-18.7)	18.4 (16.6-20.1)	19.3 (17.3-21.2)
60-day	8.51 (7.84-9.21)	10.6 (9.75-11.5)	12.7 (11.7-13.8)	14.2 (13.1-15.4)	16.1 (14.7-17.4)	17.3 (15.9-18.8)	18.5 (16.9-20.1)	19.6 (17.9-21.4)	21.0 (19.0-22.9)	21.9 (19.8-24.0)

Figure 2. NOAA Atlas 14 Point Precipitation Data

Figure 3. Road Crossing (First of Two Photos; Downstream to the Left)

Figure 4. Road Crossing (Second of Two Photos; Downstream to the Right) with Visible High Water Marks and Debris Accumulations

The concrete road crossing lies within the reach that was included in the HEC-RAS hydraulic model developed for the Sonoita Creek Project. Figure 5 shows the HEC-RAS model schematic and the location of the road crossing.

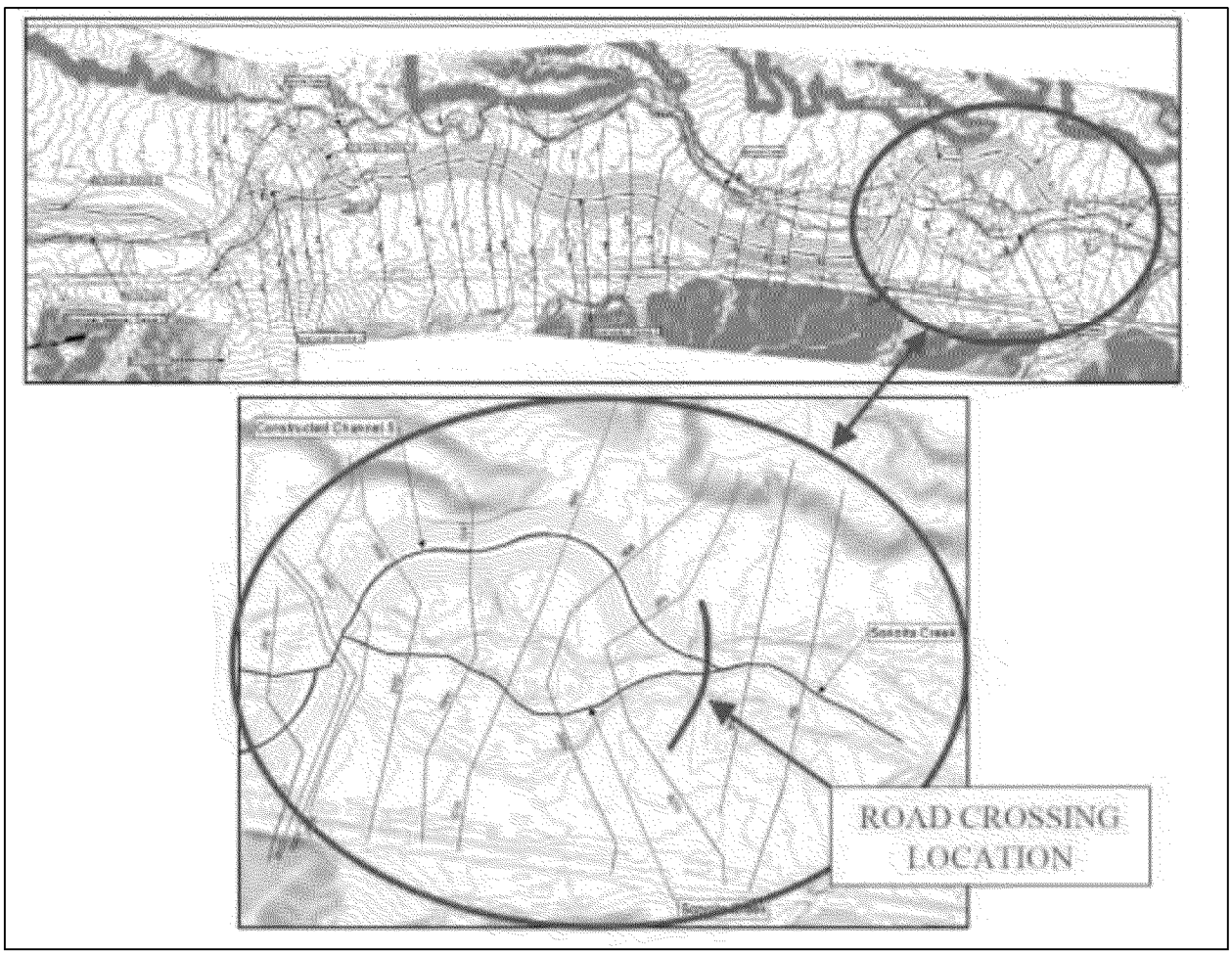

Figure 5. Road Crossing Location

For computational simplicity, a smaller HEC-RAS model focusing on the southern end of the project site was developed. Three cross sections were added to represent the road crossing, defined by an entrance section, exit section and drop off section. Manning's n values were adjusted for the concrete crossing to 0.020. Values of Mannings' n for the remaining channel sections remained at 0.035, as they had been in the previous model. Based on field observations and the presence of the drop-off downstream of the concrete road crossing, the HEC-RAS model for the road crossing was set to make "mixed flow regime" calculations rather than assuming that flow through the reach will be uniformly sub-critical (deep and relatively slow). Supercritical (shallow, high-velocity) flow is a possibility in the vicinity of a drop for some discharges, and in this case the model did predict from the flow energy calculations that the drop at the concrete road crossing would result in transitions between flow regimes for the modeled discharge. Except for enabling the model to

consider mixed flow regimes, the hydraulic reconstruction for the July storm used the same methods that were employed for the original study:

The point precipitation value of 2.76 inches was reduced by applying an aerial reduction factor of 0.747 to get a value of 2.06 inches.

The adjusted rainfall was modeled in SEDCAD to determine the associated peak discharge. The SEDCAD-predicted discharge through the section from the July rainfall was 3,667 cubic feet per second (cfs).

The peak discharge estimated by SEDCAD was simulated using the HEC-RAS hydraulic model and the resulting depth of flow in the cross section was compared to the observed depth of flow based upon the high water marks. The 2-year, 24-hour discharge of 2,346 cfs and the 5-year, 24-hour discharge of 4,004 cfs were also modeled. The profile view of the water surface elevations through the modeled reach are shown for all three discharges in (Figure 6).

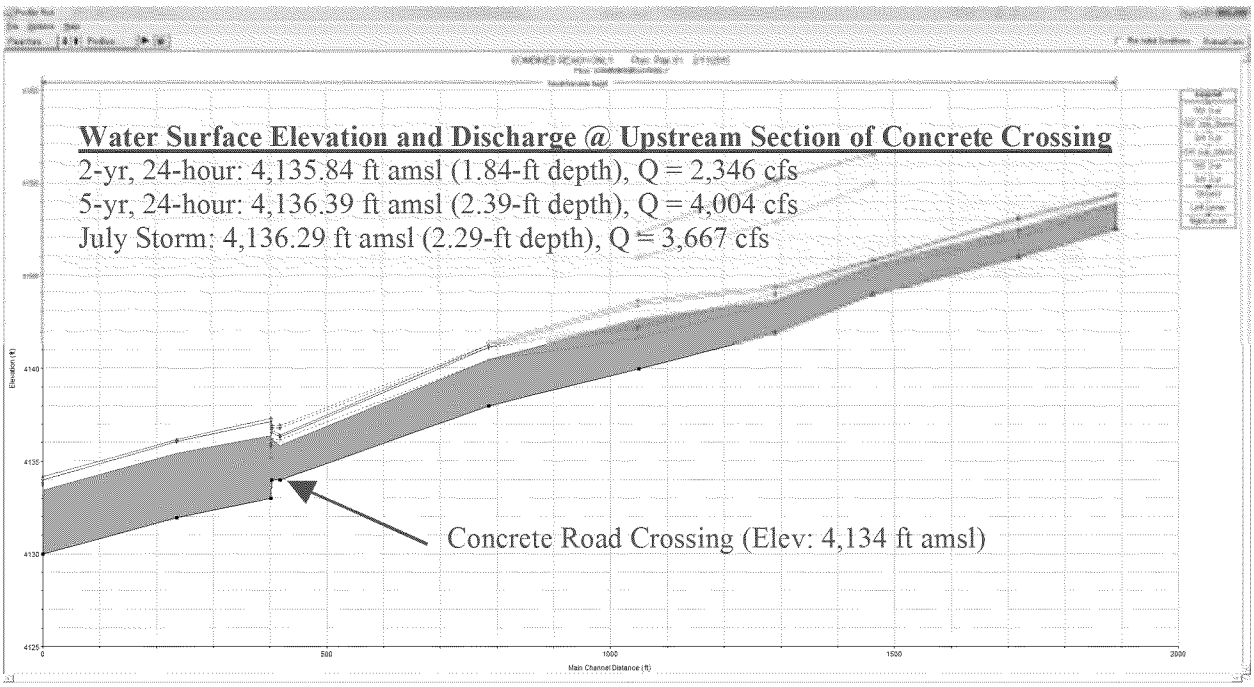

Figure 6. HEC-RAS Model Output: Water Surface Elevation Profile Plots

The depth of flow for the modeled peak discharge corresponds closely with the flow depth inferred from high water marks observed in the field, even though the peak discharge was determined independently through hydrologic modeling of the gage-recorded rainfall. The close correlation between the hydraulic model and field observations of high water marks also lends confidence to the determination that the July storm was indeed between a 2-year and 5-year event.

4.0 Summary

Data for the July 27, 2014 storm and flow event in Sonoita Creek were available for comparison with the simulated watershed response that was developed theoretically for the preliminary

design of the proposed Sonoita Creek mitigation/restoration project. Data from a nearby ALERT rain gage and from measurement of high water marks visible in the field were used to independently characterize watershed response using the same methods that were used for the project's theoretical hydrologic and hydraulic simulations. The results of this analysis indicate that the recurrence for the July 27 storm was between the 2-year, 24-hour and the 5-year, 24-hour theoretical events for rainfall, and that the expected depth of flow from such an event predicted theoretically is very comparable to the depth of flow observed in the field.

5.0 References

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